DIAMETER GROWTH IN BOX ELDER AND BLUE SPRUCE

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(WITH THREE FIGURES)

It is the common belief that trees grow throughout the greater part of the vegetative period, the commonly called "growing season," which is roughly defined as being limited to the period from the last killing frost in the spring to the first killing frost in the fall, when the broad-leaved hardwoods such as maple, ash, and aspen show their autumnal colors. In the Rocky Mountain forest region this period comprises from 75 to 100 days. Until recently little was known as to the exact time at which trees actually make their diameter growth. Neither has the course of growth nor the formation of the annual rings or cones of wood been measured until recently.

About twenty-five years ago FRIEDRICH (2), an Austrian forester, devised instruments capable of measuring the daily growth in diameter of trees. Somewhat later he improved his accretion autograph, as it was called, by adding an electric attachment which recorded the growth in the investigator's office. He would entertain his visitors by telling them that while they could not hear grass grow, they could not only see but hear the tree in the park grow, the increase in the periphery being announced by the sounding of a signal.

In 1918 MACDOUGAL devised a new instrument for recording in minute detail the daily and seasonal growth and all changes in the size of the trunk of a tree. The instrument is called a dendrograph. The essential part of it consists of a yoke composed of slotted bars of some alloy, such as bario or invar, which has a very low temperature coefficient. This is held in place by upright pieces of brass wire seated in small brass plates, which afford flexible supports capable of uniformly adjusting any tension which may be developed. These plates are clamped to a belt of wooden blocks hinged together and fastened securely to the tree, serving as a rigid support for the instrument. As this belt comes in tangential contact with the tree at only a few points, it interferes very little with its normal growth. The recording apparatus consists of a drum carrying a record sheet, the drum being rotated by clock work. In order to minimize the effect of the shrinkage and expansion of the bark, it is rasped or shaved down so that a very thin layer of cork covers the living inner bark on small spots just large enough to give suitable bearings under the contact screw and under the end of the bearing lever. Changes in the diameter of the tree trunk, that is, between the contact screw on the opposite side of the tree and the arm of the bearing lever, are accurately traced on the sheet of record paper on the drum by the recording pen. In this way a continuous curve is traced on the revolving drum as it passes beneath the point of the pen, the position of which is gradually changed as the tree trunk expands in the process of growing. The instrument is protected from the weather by a tin cover attached to the tree. The clock requires winding and the record sheet must be changed at least every seventh day. When the instrument is once properly adjusted it requires no further adjustment except such as may become necessary owing to the growth of the tree. Fig. 1 shows the dendrograph on a blue spruce tree, with tin cover removed to show the recording mechanism.

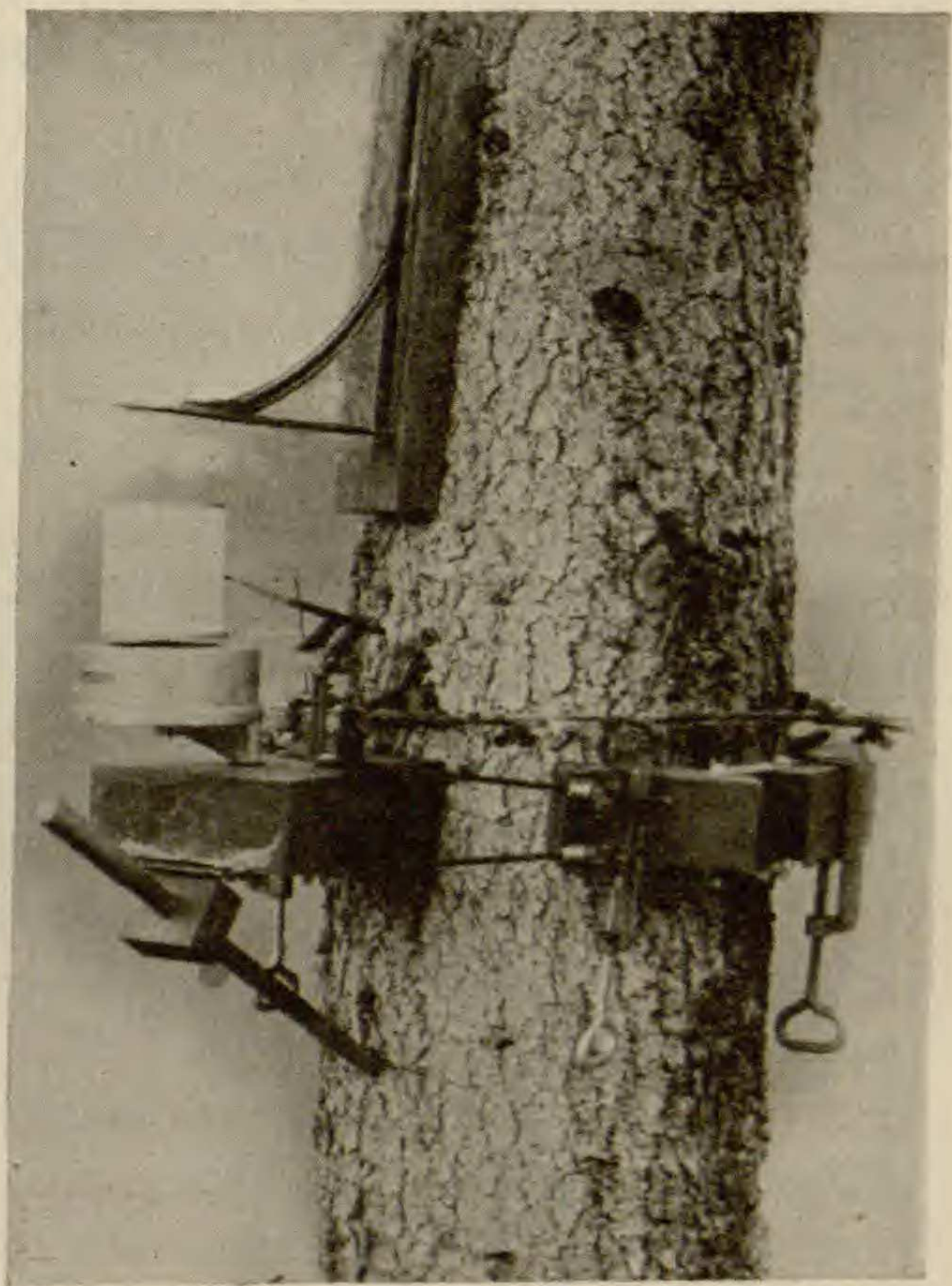

FIG. 1.—MacDougal dendrograph in operation on a blue spruce, showing encircling belt of wooden blocks and yoke of invar, but with tin cover removed to show recording mechanism.

During the spring and summer of 1920 the writer had the privilege of operating one of MacDougal's dendrographs in cooperation with him. Because of the backward season in the mountains, the instrument was placed on a specimen of *Acer Negundo* in the city of Ogden, Utah, on April 1, 1920, for the purpose of determining when growth actually begins in this species. A period of unusually cold stormy weather followed the installation of the instrument, during which quiescence and alternate shrinkage and enlargement were recorded. The tree showed some enlargement April 10–14, which, however, did not continue during the following four days when high winds prevailed. Diameter growth did not properly begin until May 19. The buds were just beginning to swell on April 1. By April 27 practically all of the leaves had unfolded, and on May 5 they were about one-fourth full size. The leaves had reached about one-half their natural size before the main period of growth began on May 19.

Fig. 2 shows the daily march of the diameter changes. In order to afford a closer correlation, the march of the daily mean temperature of the air and of the cortical layer adjacent to the cambium or the zone of living tissue where the diameter growth actually occurs is plotted in the lower part of the figure. The greatest and smallest diameters reached during the day are plotted in the upper graph to show the diurnal variations. These diurnal changes apparently vary to some extent with the range in temperature. On cool cloudy days with relatively warm nights, which have small temperature ranges, the diurnal change in the diameter is slight, while on warmer clear days with cool nights, having a great diurnal temperature range, the diurnal shrinkage or expansion may amount to as much as 0.5 mm., indicating a direct temperature relationship. Moisture conditions are not considered among the critical factors causing the commencement of growth in the spring, because the soil is abundantly supplied with moisture from the melting of the winter snows and from the spring rains, until considerable growth has been made and fairly high temperatures obtain. As might be expected, there is a somewhat close correspondence between the trend of the two graphs, although the cambial temperature does not usually attain the extremes reached by the air temperature.

On June 7 the dendrograph was moved to the Cottonwood Nursery, twenty-five miles southeast of Salt Lake City, Utah, and placed on a specimen of *Picea Parryana* growing in the nursery grounds at an elevation of 7400 feet. At this time the spruce buds were bursting open and diameter growth was already under way,

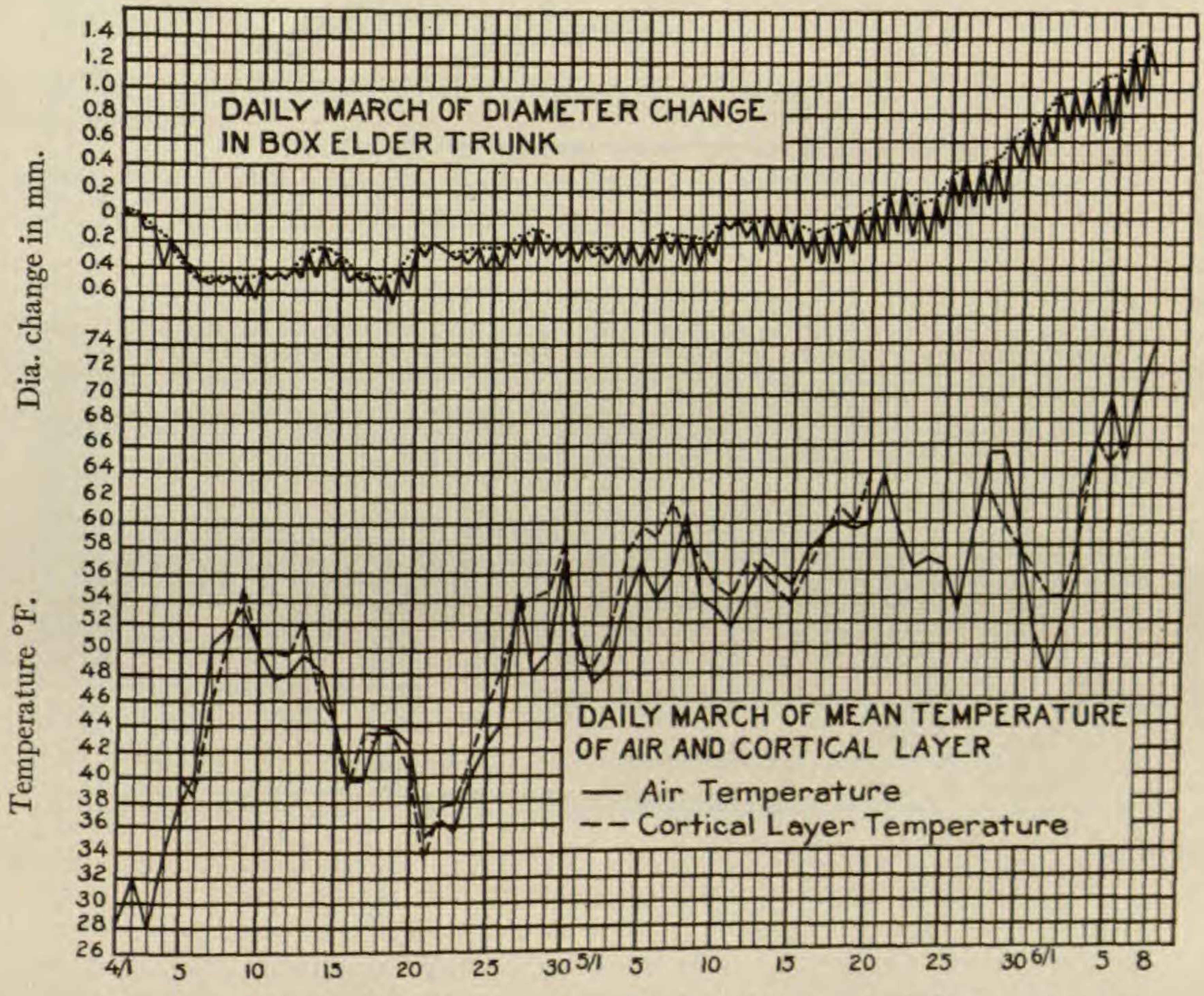

FIG. 2.—Daily march of diameter change in box elder trunk, daily mean temperature of air and cortical layer adjacent to cambium; Ogden, Utah, April 1–June 8, 1920.

as indicated by fig. 3, although it is not probable that much growth had taken place before the record began. Growth continued for slightly more than five weeks, except for two rest periods of two days each (June 19–20 and June 26–27). The shrinkage noted on June 9 and 10 may be a rest period, or it may possibly be due to a shrinkage occasioned by the drying out of the thin layer of cortical tissue after the main portion of the outer bark had been removed. In addition to the mean daily temperatures of the air and the cortical layer adjacent to the cambium, the mean daily temperature of the soil at a depth of 12 inches is also shown in the same figure for comparative purposes. No direct correlation between the march of diameter growth and current temperatures was found. A careful study of the graphs leads to the inference

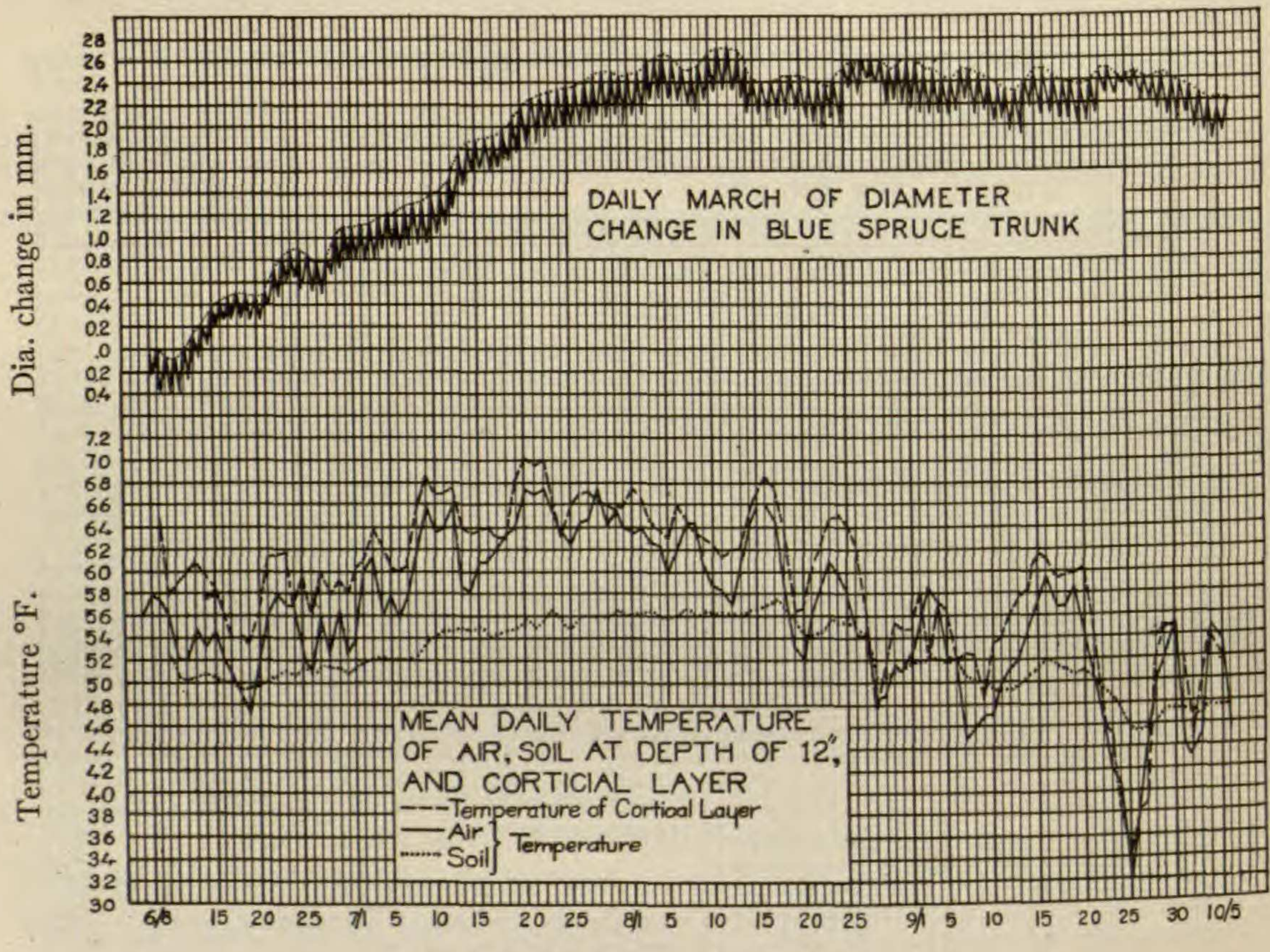

FIG. 3.—Daily march of diameter change in blue spruce trunk, daily mean temperature of air, soil at depth of 12 inches, and cortical layer adjacent to cambium; Big Cottonwood Canyon, 25 miles southeast of Salt Lake City, Utah, June 8–October 6, 1920.

that the growth response lags behind the temperature, a marked drop in the temperature causing a decrease in or even a cessation of growth[1]. HARTIG (4), as a result of extensive investigations, advanced the theory that the awakening of cambial activity was

[1] Since writing the preceding, an interesting temperature relationship was observed on a blue spruce tree growing on the writer's lawn in Ogden, Utah. On May 12, 1921, the buds on the north side of the tree had swollen and were just beginning to open, while on the south side practically all buds were open and new growth of 3–5 cm. had taken place on the tips of the branches. This difference in the inception of growth is believed to be due to the higher temperatures to which the buds on the south side of the tree were subjected.

dependent upon temperature, and that soil temperature, insolation, and the thickness of the bark were influential factors also.

GROSSENBACHER (3) has reviewed the varied and rather contradictory literature concerning radial growth in trees, the time of beginning and ending of cambial activity, and the factors thought to determine its distribution. He found a rather general agreement that, in our zone, wood formation generally ceases by mid-August, while that of the phloem continues practically to the end of the vegetative season. HARTIG (5) concluded that cambial activity first began in the youngest twigs and then gradually proceeded downward. HASTINGS (6) found that radial growth commenced first behind the opening terminal buds in broad-leaved trees and proceeded toward the base. By the time the five to six-year branches were forming new wood, radial growth had become general all over the trees. In the case of pine radial growth apparently commenced on the two or three-year old portions of branches before the buds opened. Growth started on the two-year pine branches possibly because the leaves were retained two years, for it was noted that in hemlock, where the leaves were retained six to seven years, radial growth appeared to have started first on six-year old branches. In *Taxodium distichum* radial growth started first just behind the opening terminal buds, as in broad-leaved trees, in which diameter increase did not begin until the buds had opened. REICHE (8) also noted that radial growth of trees in Chile began after the buds burst, and that it did not occur unless bud development preceded it. BUCKHOUT (1) reported diameter increase in *Larix europaea* to be practically coincident with the formation of new leaves.

KNUDSON (7), as a result of several years of investigation, including microscopical studies, found that the development of xylem in *Larix laricina* began a month later than the commencement of leaf formation, and ascribed BUCKHOUT's observed diameter increase mainly to a preliminary swelling of the tissues. From his results and those of other investigators, KNUDSON believes it probable that in general diameter growth does not begin until the leaves have developed and have become sufficiently active photosynthetically to supply the requirements of rapid cell formation. The reserve food materials stored up in the autumn are probably largely utilized in leaf and also in blossom formation, when the latter precedes leaf formation.

The most interesting fundamental principle of growth exhibited by the records obtained from the box elder and blue spruce trees is that growth evidently does not begin in deciduous hardwood trees and in evergreen conifers at the same time. These observations in general agree with the conclusions of KNUDSON. It would appear reasonable to assume that diameter growth proper, as distinguished from any preliminary swelling of the tissues which might occur, may be delayed until the new leaves are sufficiently developed to elaborate the supply of food needed for the rapid growth which takes place. The supply of stored food which is present in the spring is largely consumed in the formation and development of the new crop of leaves to a stage when they can supply the quantity of elaborated food necessary for the growth processes. On the other hand, the evergreen conifers, having an adequate amount of living leaf tissue, are capable of supplying the requisite materials for growth as soon as growing temperatures are reached in the spring. In other words, the inception of diameter growth in evergreen conifers may practically be simultaneous with the bursting of the buds, while in deciduous-leaved hardwoods it may be delayed until the new leaves have attained a sufficient size to manufacture their own food.

It will be noted that the march of diameter growth is interrupted by rest periods of rather short duration. These rest periods are held to be essential for the maintenance of the proper health and optimum efficiency of the vital activities of the tree.

Figs. 2 and 3 combined outline the seasonal course of diameter growth as follows. It begins slowly, and after a variable period increases rapidly by leaps and bounds, alternating with rest periods, until a maximum rate is attained; after a short time it gradually decreases to a minimum, and then ceases altogether, when the usual alternate shrinkage and expansion (due to the changes in temperature and moisture conditions of the tree trunk) are exhibited.

Aside from the scientific consideration of the fundamental principles of growth, the use of such an instrument as the dendrograph has several practical applications. In connection with the measurement of permanent sample plots, the question has often confronted the forester as to when diameter growth occurs and whether it is coincident with height growth. It is very frequently much more desirable from the standpoint of expediency to measure the plots during the summer than in the fall and winter, when the trees are known to be in a dormant condition. An economic consideration is in connection with the peeling of logs and poles, where this practice is necessary. It is a well known fact that peeling is most easily done when the sap is flowing freely, which is also the time of the greatest growth activity. It can be seen, therefore, that a determination of the beginning and ending of the period of actual growth will suggest the time during which peeling can be accomplished most easily. An accurate record of the march of diameter growth, when correlated with the different site factors, will aid materially in the determination of those factors most influential in conditioning tree growth, which is necessary as a basis for a rational silvicultural practice.

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